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CHEMICAL MICROSCOPY*

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A speaker who has the temerity to address a joint meeting of two different technical societies always finds himself in an awkward predicament. He feels that he must present his subject from the viewpoint of each group of men, that he must lay equal emphasis upon all branches of the sciences represented by his audience. I find myself very much embarrassed, realizing this, and in doubt whether I am here in the guise of a microscopist or of a chemist.

This, gentlemen, is the introductory paragraph of the paper I had originally prepared. Since that time we have entered the great war and I know where I stand. I come to you as a chemist to make an appeal for a wider and more intelligent application of the microscope in every day chemical practice.

If the talk appears rambling and fragmentary I trust you will bear with me, for with several momentous issues on the hands of my department I have had little opportunity to prepare a new paper and none to make new lantern slides. I will, however, attempt to stick to my text—Chemical Microscopy. To my mind there is no such thing as microchemistry as opposed to macrochemistry and the term microchemical methods is a misnomer. A microchemical reaction or test may be one performed upon minute amounts of material without necessarily having recourse to the microscope.

Chemical Microscopy on the other hand requires that some type of magnifying optical instrument enters into the work. By chemical microscopy, therefore, we simply mean the application of microscopic methods to the solutions of problems arising in the chemical laboratory or in the chemical industries.

No instrument at our command can do so much or throw so much light upon obscure problems with so little expenditure of time, labor and material. We chemists have been wasting golden hours and slaving over sloppy methods to accomplish ends which could have been reached easily and leisurely and with a degree of certainty unsurpassed by anything we have had at our command with test tubes and beakers. Why spend hours upon a qualitative analysis that can be better done through the medium of the microscope in several minutes?

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*Address delivered before a joint meeting of the Chicago Section of the American Chemical Society, and the State Microscopical Society of Illinois, at the City Club, Chicago, on April 20th, 1917; Messrs A. V. H. Morey, Chairman of the Chemical Society and N. S. Amstutz, President of the Microscopic Society, presiding. A number of self explanatory plates accompanying this article are found as inserts following page 156.

The time has come when we can no longer be satisfied with time-consuming operations. Industries must be speeded up, production increased, better inspection methods introduced, quality thereby raised and final cost in consequence reduced. I am simply preaching good conservation. If we fail in this war and disappear as a nation it will be because we have failed in our industries to produce the necessary material and the requisite quality. I cannot recall a single great industry today where microscopic methods intelligently applied will not lead to more or less marked improvements.

The causes of our failure fully to appreciate the value of microscopic methods are not hard to find. In the first place in the educational system of our chemists no adequate training has been given in the multiplicity of uses of the microscope and its potential industrial applications. In the second place too much emphasis has been laid upon biologic microscopy; so that the generally accepted view is, that this instrument is intended for studies in biology or medicine. As a result, the development of the modern so-called high grade microscope has followed strictly biological lines and has drifted farther and farther away from stands applicable for general work in the chemical laboratory. For example the best of our present day stands no longer have the mirror mounted upon a swinging bar capable of movements far to one side, or even above the stage for oblique illumination. In refractive index work, in the observation of melting points, in the study of fatigue failure in metals, in the general examination of alloys, cements, protective coatings, etc., and in the preparation of photomicrographs of certain preparations, this old device now abandoned is really essential, and it is necessary to remove the mirror from the stand and fasten it to a holder of some sort that it may be properly employed.

It is also unfortunate that the objective of small angle, long available working distance and marked penetrating power are not obtainable save at second hand. The modern microscope objective is a marvel in its performance, yet it is limited to the study of mounted materials covered wtih a standard cover glass if over a moderate power is required for the examination; but unfortunately, we chemists must work with uncovered preparations and we must sacrifice resolving power for penetrating power and for stereoscopic effects. We need instruments of moderate cost, substantially built, and which will withstand the corrosive atmosphere of most of our industrial laboratories. Thus the third reason for the backwardness of chemists to use the microscope has been the lack of suitable models and accessories. Even our good friends and near chemists, the petrographers, have never gone out of their narrow way, to try to impress the chemist with the fact that the polarizing microscope is an indispensable adjunct of the research laboratory. The modern petrographic microscope is a measuring instrument of great precision. By its means alone a vast number of chemical compounds can be positively identified. The manufacturer of organic compounds, especially, cannot afford to ignore it as a means of increasing the ease of control work. In the hands of a skilled worker this type of instrument offers untold advantages.

The application of microscopic methods to analytical problems should appeal to every chemist. Not only can he perform qualitative chemical analyses easier, but he can measure refractive indices of both solids and liquids, determine melting and boiling points with exceptional accuracy and upon minute amounts of material which cannot be isolated; determine molecular weights and can study the structure of most of our commercial materials. Dr. Harvey W. Wiley, in one of his happy moods, once defined chemistry as "the astronomy of things infinitely small." Our telescope is the microscope. To make suitable progress we must, like the astronomer, construct special instruments for special purposes and like the astronomers we must become specialists in narrow fields within our vast science. We chemists must have analogues to the students of double stars, to the investigators of nebulæ, to the seekers for comets, etc., when this day comes the results reported will be comparable to the discoveries of our astronomical friends. Americans make the finest telescopes in the world. Why not microscopes as well? Unfortunately the scientific world in the United States has been obsessed with the idea that no microscopes are worth using, unless made in Europe. We are all to blame for the present difficulties. Can you obtain an ultramicroscope, a luminescense microscope or even a polarization microscope in the United States this 20th day of April? Not one, nor can you obtain condensers, lenses and eyepieces of quartz suitable for photography with ultra violet rays, nor spectroscopic oculars; nor can be purchase a really satisfactory moderate-priced metallograph, although in this line there is hope that instruments will soon be on the market.

If each one of us here tonight will agree hereafter to stand by American manufacturers and buy American made instruments, we will soon have special microscopes and accessories ranking with the best obtainable. Our artisans have no superiors and few equals, but in order that we may persuade them to undertake the construction of the apparatus we require it is essential that we must support them with advice and hard dollars and not with empty applause. It is easy to find fault and refuse to cooperate; but it takes time and tact to call attention to defects and suggest improvements.

If those using special microscopes would stop and consider the care and labor involved in their construction and would be a trifle more tolerant toward mistakes in construction, far greater progress would be made than at present. Let us all agree to try and stimulate the development of American types of microscope which will do our work better and easier, and cease being mere copyists. Let us become "boosters" instead of "knockers".

I have already asserted this evening that the chemical microscope will do more for the chemist than any other instrument or group of instruments, and it behooves me to prove my contention. In the first place microscopic methods are the simplest and shortest for the identification of a compound. Let us assume that the analyst has in his hands a crystalline salt, and by qualitative analysis in the usual manner he decides after about an hour's examination that it contains sodium and phospheric acid—nothing else. It is manifestly a sodium phosphate, but which one? Mono, di or tri? This he can answer satisfactorily by quantitative analysis, and actually only by a determination of Na and PO_4. If, however, he possesses a polarizing microscope, the problem is quite simple. The mono-sodium salt is orthorhombic, the di-sodium, mono-clinic, while the tri-sodium phosphate is hexagonal. He can clinch his opinion with one or more simple optical measurements and prove his case by refractive index determinations by the immersion method. Why is it that the chemist never uses refractive index determinations by means of the microscope as an aid in qualitative analysis? It is inconceivable that we have had these methods used for years by mineralogists and petrographers, yet never had sense enough to apply them to our own ends and thereby save ourselves hours of time.

But to go back to our phosphate; had we made the qualitative analysis by microscopic means it would not have taken us an hour, but say not over half that time. We would have been seated comfortably at a table and would have satisfied ourselves in a very few minutes that the salt was di-sodium phosphate badly effloresced and of commercial, not C. P., quality. This case is actually a typical one and very simple. I have selected it because it illustrates quite clearly the way in which a simple salt may be identified. But I hear some of you say this requires a knowledge of crystallography. What of it? If this knowledge will save us time and labor let us by all means do a little reading.

Of all the inorganic salts we will meet with in industrial work only a very few belong to the isometric system and have no effect upon polarized light. Very few tetragonal and triclinic and fewer still hexagonal. There is rarely need for expert training to enable the analyst to properly place the compound under examination in one of these systems. Suppose again the analyst has an inorganic crystalline salt, and under the microscope it separates from water in what appears to be large colorless octahedra which are isotropic. The salt must be an alum, or strontium, barium, or lead nitrate, or one of several chlorostannates. The addition of a tiny drop of nitron sulphate gives no crystalline precipitate, therefore it cannot be Sr, Ba or Pb, or other nitrate. A little calcium acetate gives crystals of calcium sulphate. The salt is presumably, therefore, an alum. A refractive index determination will show which alum, or we can go ahead and test qualitatively for the bases present.

The point I wish to emphasize is that in the identification of many substances a systematic time-consuming analysis is unnecessary. Note well also that all the work is done upon an object slide, that only low powers are employed and the amount of reagent required is negligible. Five grams of practically any reagent used should last an analyst, even in daily examination, almost a lifetime.

I find that the prevailing idea among chemists is that qualitative analysis, by means of the microscope, has for its purpose, the detection of infinitesimal traces of material such that all other methods fail. Although it is true that microscopic methods can be thus employed, by far the greatest points in their favor are the rapidity of obtaining results and the certainty of reaction. Actually the relative proportion of material to solvent is very great, we are apt to be working with high concentrations. We take a fragment of the unknown material, not quite as large as a pin-head, and dissolve it in a minute drop of water or acid. The microscope enlarges this drop of solution until it appears to have the diameter of a twenty-five cent piece. This is almost equivalent to taking a handful of the unknown and dissolving it in a litre of solvent. The identity test is made by adding a reagent which will lead to the formation and separation of a crystalline phase.

It is in the field of organic analysis that the microscope stands without any possible competitor. Differentiation of isomeric compounds, recognition of different degrees of sulphonation, nitration, etc., is so simple in most cases as to be mere child's play. Take the case of the phenol sulphonic acids. Recognition of the different acids, mono or di, ortho, meta or para or mixtures, was a stumbling block for years until Pratt showed that the barium salts were easily differentiated under the microscope. The di-acid salt forms stout mono-clinic prisms, the mono-ortho acid long slender rods, and the para acid tufts of fine needles. Quite recently the microscope was called upon to aid a large plant in controlling the completion of a certain process. It was found that the manganese salt of a certain organic compound crystallized in plates with vivid polarization colors; the other product which it was desirable to eliminate crystallized only with difficulty in sphæro crystals polarizing feebly. A glance under the polarizing microscope showed at once the stage in the transformation of one form into the other. The older method of control took not less than twenty-four hours; the new not over twenty minutes.

By far the majority of organic compounds cannot be differentiated and identified without time consuming quantitative determinations. Judicious application of the methods of what Lehmann years ago called crystal analysis yields the necessary information at once.

By means of an electrically-heated stage not only can we determine melting points with greater ease than by the usual methods, but the accuracy of our observations is considerably increased. Amounts of material so small as to be practically invisible to the naked eye can be employed. A further advantage lies in the fact that the melting points of several different substances existing in a mixture may be ascertained without having recourse to long and arduous separations, involving loss of material and time.

Very reliable melting points of fats may also be obtained as well as the boiling and subliming points of small quantities of material.

The advantages of microscopic melting point determinations will become more apparent when we recall that when we separate one compound from another at our laboratory work table, we so proceed that the final products stand upon our table a few inches apart in suitable containers. If we spread a small quantity of the original mixture upon a bit of cover glass and examine the preparation with a magnification of say fifty diameters, a decided space will be seen to exist between most of the different components. Gentle tapping will usually increase this space. To all intents and purposes the magnification has done exactly what we accomplished in our long chemical separation; i. e., removed the components from apparent contact with one another, and interposed space between them. In most instances even very rapid crystallization of two or more salts upon a slide by quick evaporation of their solution will yield a preparation in which the salts will be found to have separated without intermixture, and with a sufficient space between them to allow of a melting point determination being made.

This fact is clearly shown in Fig. 1. Evaporation has been pushed so fast as to force the salts to crystallize in dendritic forms, yet each group of dendrites is clear and distinct. Were such a preparation heated carefully and watched with the microscope, I think you will all agree that as one of the components begins to melt it will easily be discerned and will not interfere with the other. When, however, the temperature is raised to the melting point of the second component, the chances are that the two liquids will flow together. Nevertheless the moment of fusion is easily ascertained. If in melting point observations, as I pointed out some years ago, we make use of the polarization microscope, the transition from a solid anisotropic body to a completely fused isotropic body is instantly recognized.

Doubtless that branch of chemical microscopy of greatest general applicability is in qualitative analysis. The addition of a suitable reagent induces the formation of a distinctive compound and its subsequent separation as a solid crystalline phase. These crystals are easily recognized and are so characteristic that there is little danger of mistaking those given by one element or compound for those of another. Add to the distinctive morphology the fact that color also enters into the identification scheme, and it will be even more apparent why microscopic methods offer such ready means of identification. In a large number of cases one and the same reagent will cause distinctive crystals separations with a number of substances. One of the best examples of this is potassium (or sodium) mercuric sulphocyanate, $K_2 Hg(CNS)_4$ (or 2 KCNS. Hg (CNS)2) which gives characteristic crystals with copper, yellowish green (Fig. 2); cobalt, deep blue, (Fig. 3); zinc, white (Fig. 4); cadmium, colorless (Fig. 5); lead, colorless (Fig. 6); manganese, colorless (Fig. 7); gold, yellow; silver tiny colorless; and a red color with iron. Thus the addition of a single reagent will show at once the presence or absence of a number of elements, and at the same time produce an identity test for each, thereby saving an enormous amount of time and material. There are a number of such reagents available, and by carefully choosing them we can complete in a few minutes a qualitative analysis, intricate though it may be.

Time will not permit me to show slides of more than one or more of these multiple test reagents. I have selected cesium chloride, which gives us reactions for bismuth, antimony, tin, copper, silver and lead, and occasionally, aluminum and magnesium. You will note that the crystals obtained are just as different from each other and just as easily recognized as those formed by the mercuric sulphocyanates. The slides I now show you are the characteristic reactions for the common acids. You will note that the crystal forms are so different and so easily remembered that there can result no confusion when the tests are properly applied.

The amount of material required for our tests is shown by the tiny fragment clinging to an ordinary No. 7 sewing needle (equivalent to a fragment whose diameter is approximately that of a period (.) on this page). The manner in which a test is performed I have tried to show in this lantern slide, Fig. 8. An ordinary 3″x1″ object slide with the steps in the analysis of an alloy has been photographed natural size in order that the relative sizes of the drops may be better judged. The tiny black spot (0.8 mm. x 0.1 x 0.1 mm.) is a piece of the alloy of the exact size of that employed for the analysis. The large spot at the corner is the space occupied by the solution of the alloy after repeated evaporations with tiny drops of nitric acid to render insoluble any tin present. The nitric acid soluble portion has been decanted to the second spot. The residue has been tested and found to contain tin, antimony, and copper. The nitric acid solution has been divided into three drops as seen on the slide; the first shows the dry residue after finding lead, copper and antimony present; the third spot is what remains on the slide after testing for other elements and finding zinc and iron in traces, in addition to those already found. The fourth spot has been used for testing for the remaining possible metals which were not disclosed in the other tests.

We have thus carried out upon an object slide the entire qualitative analysis of a bearing metal containing tin, antimony, lead, and a small amount of copper, and having traces of iron and zinc present. Actually it took no more time to perform the analysis than it has taken time to tell it. The worker has been seated at a small table and has used less than five cents worth of reagents and gas. Instead of cutting off a small portion of the alloy we could just as well have rubbed it over a piece of ground glass or unglazed porcelain, dissolved off portions of the streak with acid and made our analysis as just outlined. The next lantern slide shows this method together with the results obtained and the time required for the analysis.

These cases are fair illustrations of what is possible in the saving of time, money and labor, through the employment of microscopic methods.

Other valuable applications of qualitative tests are those involving testing for the purity of precipitates in gravimetric analyses in order to avoid the time and trouble involved in resolution and reprecipitation, in testing for complete precipitation, especially in electrolytic analysis and also in testing for complete washing.

Another valuable application of microscopic chemical methods is in the analysis of the total solid residue in water analyses. We generally speak of the hypothetical combinations present. I do not wish to raise the question of reporting ions or combinations, but I do desire to lay emphasis upon the fact that it is possible and practicable, in most cases, to identify the salts present in the solid residue through their habit and optical properties, providing the work is properly done. I know of several instances where identification of the principal compounds present threw much light upon obscure problems. Traces or more of the heavy metals, such as lead, copper, etc., are far more readily detected by microscopic qualitative analysis methods than by any other means at our disposal.

Water analysts pay altogether too little attention to microscopic examinations of sediments and suspended matters, to the deposits at the bottom of springs, wells and cisterns. Much valuable information is also to be derived from the examination of the muddy ooze at the bottom of streams, ponds and reservoirs, and from the study of the coated sands from rapid filter beds, to learn the extent and character of the adsorption of aluminum hydroxide by the sand grains. When we speak of the "microscopy of drinking water", we generally mean researches upon the flora and fauna giving rise to disagreeable odors and tastes, but this is in reality only a very narrow portion of a huge field which is by no means restricted to biological problems or even to investigations made with the ordinary microscope, since it comprises problems soluble only by means of such specialized instruments as the ultramicroscope and the luminescence microscope.

The remaining lantern slides have been chosen to illustrate the application of microscopic methods to the solution of problems in some of the great industries. I can do no more than touch upon them. Permit me, therefore, to merely outline the nature of the information given.

Abrasives: Proper grinding requires adequate speed without undue heating, cutting of uniform depth, wheels which wear well. In other words the selection of the proper sort of wheel and speed for the specific purpose. There enters in addition, the size of particles of abrasive and the nature of the bonding material giving a hard or soft wheel. Much of the manufacturing has been done upon a purely empirical basis and by rule of thumb methods.

Microscopic examinations of particles torn off shows how the wheels have acted. While a similar examination of the ground surface shows the character of the cutting done.

It is surprising how much information may be gained in this way, and how it may be used to guide one in making proper selections.

I will be able to demonstrate that a grinding wheel of a certain kind will tear off the surface of tool steel in such a manner as to heat the steel and draw its temper to such a degree that the particles you will see under the microscope have been fused into tiny spheres. Another wheel rotating with the same surface velocity will cut off the material in ribbons. You will note how few melted fragments are present, as shown by the absence of tiny spherical masses. Such a wheel can be employed for purposes for which the other is obviously unsuited.

Cement, Concrete, Ceramics, etc.—By microscopic examination it is possible to determine the character of the final product, its component parts and their volume per cent; the prevalence of an undue proportion of air and water voids; the thoroughness of wetting of the cement mixtures, etc.

Not less important is the recognition of improper bonding and valuable information is obtainable as to the actual strength of the concrete or its liability to failure. There is here a huge field for the investigator offering untold possibilities.

The whole field of ceramics, both clay products and porcelains, needs intensive microscopic research. Even our ordinary bricks offer a most attractive subject for the investigator.

The thickness of glaze and the thoroughness of its bond with the body-making material can readily be determined. I have prepared slides of two high-grade porcelains; in one of these, Fig. 9, you will note the glaze is thick and between it and the porcelain are a vast number of tiny gas voids. In some cases these gas voids penetrate the glaze as infinitely fine capillary tubes. The other porcelain of far higher quality has a much thinner glaze and as you see, (Fig. 10), has almost no gas voids, the bonding is almost perfect. Examinations of this sort, employed in the industry, go a long ways to improve the products turned out.

Foods and Beverages: Doubtless the earliest application of microscopic methods by the chemist was in the examination of foods, food accessories and drugs for adulteration or deterioration. Examinations of this sort are based largely upon vegetable and animal histology, and differ but little, if any, from the ordinary technique of histology. No other methods are available to accomplish the ends in view, and we can therefore assume that in this line at least the microscope is indispensable, training in the necessary technique imperative, and every food analyst and expert must perforce train himself to undertake studies of this sort.

This field of activity is so well understood and so firmly established that we can dismiss it without further comment. But there is in this whole question of the microscopy of foods and drugs, another phase, which chemists have greatly neglected, that of the amazing possibilities of microscopic qualitative and quantitative analysis. To even enumerate the list of substances whose detection becomes simpler, more certain and much more rapid than by our ordinary routine tests, would require more than the remaining time at my disposal. These "micro" tests are applicable to organic, as well as inorganic substances, as I have already pointed out. We have nothing better than microscopic methods for the detection of the poisonous metals, for the recognition of the organic acids, for the detection of preservatives, for the vegetable alkaloids, glucosides, and other active principles of plants; nor can we find other methods available for the quantitative analysis of starch mixtures and for similar analyses of mixed powders and meals of vegetable origin.

The recognition of our commercial synthetic drugs also is considerably simplified. In fact it is no exaggeration to say that proper analyses of this sort cannot be conducted unless the microscope is employed.

In the canning industry, especially that employing tin cans and other containers, the microscope gives information of untold value. Soldered and crimped joints yield up their secrets, as also the tinned surface or other protective coating which may have been applied to metal or paper surfaces. The possibilities, are in fact, without end.

Metallurgical Industries: The microscopic study of metals and alloys has been so firmly established within the last few years, and the close relation between structure and physical properties so generally recognized and its importance proved in practice, that I need not spend time upon this question. Although these methods have been placed upon a firm foundation in the iron and steel industries, there is much work to be done in the great field of commercial alloys. We generally think of heat treatments in terms of steel only. As a matter of fact many alloys may be greatly improved by carefully conducted heat treatments. In order that such work may be properly done, microscopic studies of structure are imperative. This is well shown in photographs of a copper, zinc, and of a copper-aluminum alloy, which I will show you.

Often the microscopic appearance of a roughly polished and etched specimen taken in conjunction with a hasty qualitative analysis will give the investigator all the information he may require to deduce the quantitative composition, and to make a shrewd guess at the physical properties.

A most fruitful field leading to improved practices is the study of welds and brazes under the microscope. At least one expert in welding by means of oxy-acetylene owes much of his remarkable success to microscopic studies of welded materials.

Not infrequently the microscope shows that a poor product is due to improper temperatures of casting or coating, and not to bad raw materials or wrong percentage composition. This is especially the case in babbitts and in tinned goods. We have here photographs showing the great difference in the structure of a babbitt cast at too high a temperature and the same one poured just right. It is obvious that in the one case friction will be considerably greater than in the other, particularly if in a high speed bearing.

Paints, Pigments, Protective Coatings: The microscopic studies of materials falling in this class may be classed under three heads: (1) The examination of the raw materials, (2) that of the coated surfaces and (3) studies of the methods and results of applying the coatings to the objects to be protected.

Briefly stated the raw materials under the microscope (chiefly pigments, etc.,) reveal their source and nature; often the process of manufacture and their suitability for the purposes for which they have been purchased. Take for example the mere question of size in the selection of the pigments for a mixed color paint. It is a simple matter to obtain a whole series of different shades by using, say two pigments and having them vary in the ultimate size of their particles, although the per cent by weight of each remains constant. The actual shape of the particles also probably seriously effects the length of time the paint really acts as an efficient protector, especially in paints containing silica, graphite or both. The microscope also throws light upon the nature of the changes taking place in the pigments of paints on being exposed to air, light and the weather. A good illustration is to be found in the study of the cause of the darkening of lithopones.

Examination of the weathered, coated, objects, both of the surfaces and of section, cut through the thin films of coatings, not infrequently will permit the formation of an immediate opinion as to the quality of the paints or coatings, and the skill of the workmen who applied them.

Too little attention has been paid in the past to the study of sections. I believe you will all be interested in the preparations I have to show you. I have selected them because they exhibit in a striking manner the differences between good and bad paints, and between good and bad workmanship in their application. You will also note that the appearance under the microscope of these samples of japanned steel show very clearly the superiority of the one method of baking over the other: in actual practice the superior surface costs less to apply than the inferior and wears longer and better.

The microscope in the hands of the chemist dealing with this class of commercial material enables him to rapidly evaluate the products handled by his firm, to improve faulty products and to determine whether the materials supplied to the trade are being properly applied.

Nor must we omit from mention the valuable information we may obtain from the microscopic study of woods to which fire or decay-proofing substances have been applied.

I have thus far failed to mention one great industry based largely upon microscopic control—the Paper Industry. Practically, an analysis of paper without reference to its ultimate composition as shown by the microscope is of little or no value. Actually much paper is manufactured and employed for various purposes without studies under this instrument. As a necessary consequence we frequently meet with paper-fibre goods manufactured with little regard for the ends to be attained other than to sell at a profit. A fair criticism of our American paper products are that they are too good. That is to say, the quality is higher than need be, and the cost to the consumer is greater than it should be for many of the objects to be attained. By that I mean that a less expensive product would serve equally well and not infrequently better. This is poor business and poorer conservation. Let me cite a case in point.

A few years ago a firm manufacturing a product (which must be nameless, since the investigation was conducted in confidence) appealed to the laboratory for advice. Their product, and that of their competitors also, was failing to stand up under new conditions of use. In desperation the chemist of the firm wanted to know whether the microscope would reveal the source of the trouble. Critical study for a day or two of new and failed material showed that changes made by the paper firms were probably the cause of the trouble. A commercially better grade of paper was being supplied. The matter was taken up with the paper firm. The answer was quick and to the point. The paper supplied was the highest grade that could be produced at that price and further they didn't propose to have any men, mere analysts, tell them their business. They had been manufacturing papers before the questioning men were born, etc., etc. In fact the same old story and the same old trouble with many well-meaning American firms. All you industrial men have had similar experiences. I need not go further.

A small firm was prevailed upon to make a paper of a kind which, it was believed, would eliminate certain features which the microscope seemed to indicate to be the cause, or at least one of the causes of the troubles. This new paper was then treated in the proper manner and tested out. The results were so satisfactory that a contract was placed to take the entire output of the paper firm with specifications as to the kind of paper needed. The net result was that a product was obtained in which, not only were the old defects eliminated, but the cost of production was decreased, the final profit greatly increased, and the stability of this industry assured. But I am not sure that the paper firm which lost a large contract is even today convinced that the new methods of microscopic investigations are of value.

There is little doubt that similar conditions obtain in many of the other varied paper-fibre industries. Microscopic methods are the only ones which enable the analyst to identify the nature of the paper and to indicate its fitness and adaptability for the specific uses to which it will be put.

The technique for the recognition of the nature of the fibres present and for their quantitative determinations are fairly well established and are on the whole, quite satisfactory. But a phase of microscopic investigation has been neglected. A study of the finished surface with reference to the uses to which the paper is to be applied. A study of paper surfaces with vertical illuminator and with oblique light yields most interesting results. Were these methods more often employed there would be, in many cases, a decided modification in certain papers on the market.

The Textile Industries: Like paper, the analyses of textiles and the recognition of the fibres of commerce are dependent entirely upon the proper application of microscopic methods. At the present time no other satisfactory methods are available for differentiating between the species of fibres employed, the specific treatment they have received, or the loom arrangement by which the yarns have been woven into fabrics. In not a few instances the information thus obtainable may go even farther and disclose the nature of the method used in dyeing the yarn or the fabric. Uneven adsorption, variable penetration, etc., are easily recognized. The skilled investigator may go even farther and discriminate between different qualities of the same species.

The technical microscopy of the textile fibres is still in its infancy, its literature teems with inaccuracies and contradictions. Too little attention has been devoted to the investigation of the reactions of reagents and the selection of proper differentiating stains, and the potential possibilities of dark field condensers having very oblique ray illumination (ultramicroscope) and of luminescence illumination (ultra violet rays) have not yet received the attention they deserve.

By way of illustration of what the microscope reveals, I call your attention to several lantern slides selected to show how neglect to employ this instrument led to the failure of a manufacturer to reproduce a fabric which his firm was called upon to manufacture because of war conditions. The reproduction involved producing a similar yarn from like fibres, a similar weave in the fabric, and a similar colored printed pattern. You will see that in no case was he successful and that his different attempts were a waste of time, material and energy, since he apparently lacked the fundamental microscopic information necessary for success.

I trust that in these rambling remarks I may have converted some skeptics to a belief in the importance of chemical microscopy in our industries, and may stimulate a wider interest in a branch of chemical analysis whose value has been greatly underestimated and whose development has been sadly neglected.

EXPLANATION OF PLATES

Plate XI. Fig. 1. Crystallization upon an object slide even so rapid as to lead to the formation of dendrite crystals rarely results in contact between the crystal groups. Melting points may often therefore be determined without the necessity of separating constituents. In the field photographed are crystals aggregates belonging to the isometric and to the monoclinic systems.

Plates XI, XII, XIII, XIV. Figs. 2, 3, 4, 5, 6, 7. A single reagent often gives very different crystals with different elements. The illustrations show the crystals produced by the action of potassium mercuric sulphocyante upon solutions of salts of the elements listed below. Thus, by adding a single reagent the presence or absence of many substances may be at once indicated effecting a saving of time, labor and material.

Fig. 2. Reaction with Salts of Copper, giving $Cu(CNS)_2\ {}^{\circ}Hg(CNS)_2\ {}^{\circ}H_2O$, color, greenish yellow.
Fig. 3. With salts of Cobalt, $Co(CNS)_2{}^{\circ}Hg(CNS)_2$; color, deep blue.
Fig. 4. With salts of Zinc, $Zn(CNS)_2{}^{\circ}Hg(CNS)_2$; color, white.
Fig. 5. With salts of Cadmium, $Cd(CNS)_2{}^{\circ}Hg(CNS)_2$; colorless.
Fig. 6. With salts of Lead, $Pb(CNS)_2{}^{\circ}Hg(CNS)_2$; colorless.
Fig. 7. With Manganous salts, $Mn(CNS)_2{}^{\circ}Hg(CNS)_2$; colorless.

Plate XIV. Fig. 8. Illustrates the amount of space required to perform the complete analysis of an ordinary commercial alloy (Babbitt). The photograph is that of the end of a standard 3x1 in. object slide upon which an actual analysis has been effected. The spots show where the tiny fragment of alloy was dissolved, reagents applied, and decantation of drops from one place to another practiced. Since the quantities of material required are small the time consumed and the amount of reagents required are reduced to a minimum.

Plate XV. Figs. 9, 10. Show the application of microscopic methods to the study of ceramic glazes. Fig. 9 shows a thick glaze improperly bonded and filled with gas bubbles. Fig. 10 a thin glaze closely adherent to the porcelain and containing very few gas bubbles.

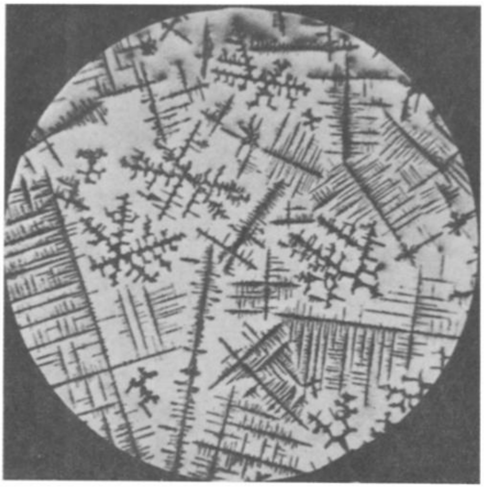

Fig. 1

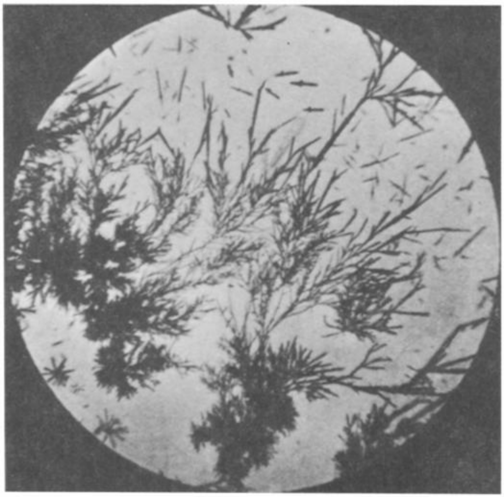

Fig. 2

Plate XI

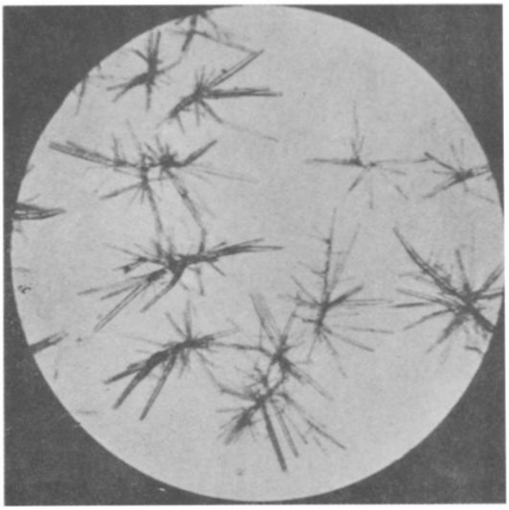

Fig. 3

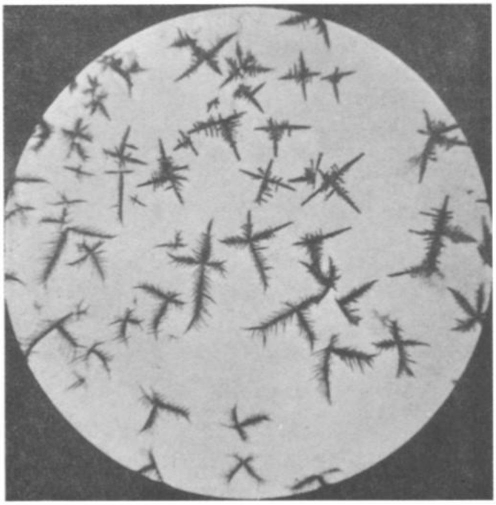

Fig. 4

Plate XII

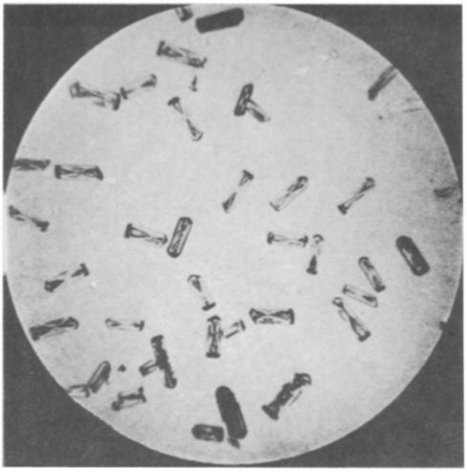

Fig. 5

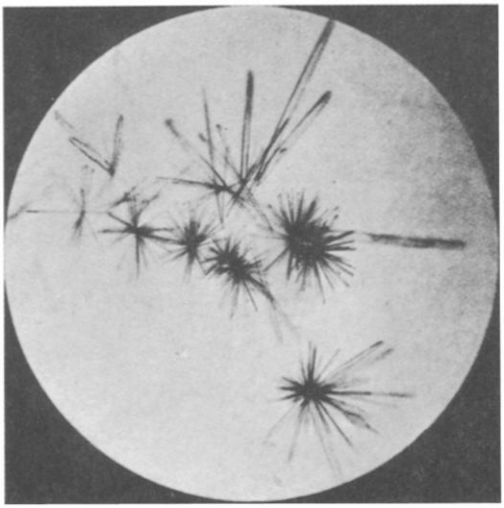

Fig. 6

Plate XIII

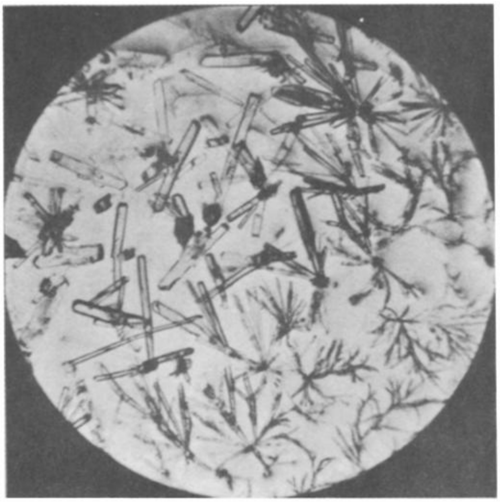

Fig. 7

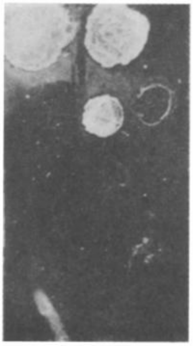

Fig. 8

Plate XIV

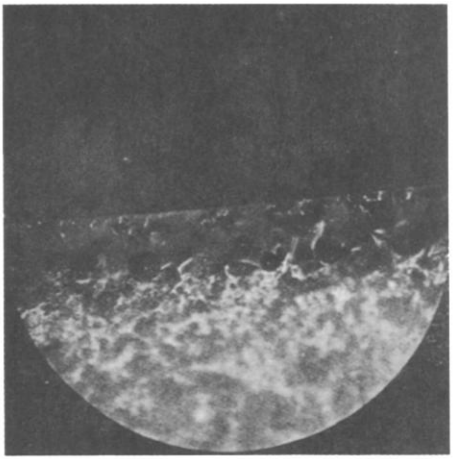

Fig. 9

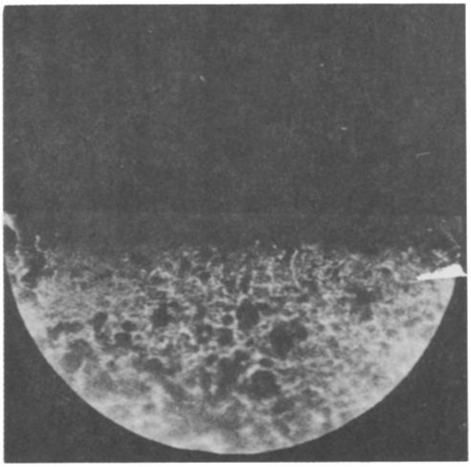

Fig. 10

PLATE XV